The concentrations of PCB in the sediments of the disposal area are of the same order as those known to be toxic to many species of molluscs and crustaceans (Goldberg, *et al.*, 1971). The high levels found in *Chlamys septemradiata* are of particular interest, as this species is closely related to the commercially fished *Chlamys opercularis.*

Conclusions

The disposal of sewage sludge-containing PCBs in the Firth of Clyde has resulted in heavy contamination of the sediments in a confined area. The distribution of PCBs in the disposal area parallels that of a number of other pollutants. There is also a more widespread low-level contamination of surface sediments, probably as a result of PCBs being transported in association with fine organic particulate material. The contamination of the benthic fauna reflects that in the sediments. The levels of PCBs in the sediments may contribute to the reduced faunal diversity in the centre of the disposal area (Mackay & Topping, 1970).

With the restrictions imposed by the manufacturers on the use of PCBs, and the elimination of other sources in the Clyde catchment area, the levels of PCBs in the Garroch Head area are expected to diminish. A 66% reduction in the levels present in the sewage sludges has already been reported (Cunningham, *et al.*, 1972). Monitoring of PCB levels in the Garroch Head area will be continued over the next few years.

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Seabird Mortality in the North Irish Sea and Firth of Clyde Early in 1974

12398

Heavy mortality of guillemots in the Irish Sea was recorded in 1969 and was the subject of a detailed enquiry. Organochlorine contamination was thought to be a contributory factor, although this could not be conclusively established. These persistent pollutants remain in the environment and further mortalities might be expected if they were indeed responsible. In January, 1974 there was a further heavy loss of seabirds in the area and, this time, investigators were prepared and the incident was carefully monitored.

In the autumn of 1969, great public concern was caused by a mass mortality of Guillemots (*Uria aalge*) with smaller numbers of Razorbills (*Alca torda*) along the west coast of Britain, and by the discovery of unexpected amounts of organochlorines and heavy metals in some of the bodies. While it seemed likely that this mortality was precipitated by a combination of stresses, such as food shortage (though this could not be demonstrated) and gales, it was postulated that it might have been made worse by pollution, and especially by the liberation of the lipid-soluble organochlorine as the birds consumed their fat (Holdgate, 1971).

If this was so, and these compounds remained in the ecosystem, it might be expected that the mortality would recur at intervals. The Royal Society for the Protection of Birds Seabird Group beached bird survey, which detected the original disaster, was therefore maintained partly to provide continuing surveillance, with concentration of the routine surveys into five weekends between September and March from 1971, to more easily obtain comparable results (Bibby & Bourne, 1972). By the time the next large incident of this type occurred in January, 1974 more than 1,600 km of shore in Britain and Ireland were being covered in each survey.

The Incident

The routine survey of January 26–27, 1974 revealed an increase in the usual level of mortality from Caernarvon in North Wales around the northern Irish Sea to Buteshire in south-west Scotland and the east coast of northern Ireland, as shown in Fig. 1. Guillemots were again the main species affected, with fewer Razorbills, and a wide variety of other species, especially Shags and Cormorants (*Phalacrocorax aristotelis* and *P. carbo*) as shown in Table 1. The way in which mortality increased in this area in this year, compared with the relatively unaffected east coast of Scotland and the previous year in both areas, is also shown in Table 2. Only 11% of the auks from the north Irish Sea were oiled in January, 1974 compared with 81% of the much smaller total for the equivalent survey of the previous year. As in 1969, many of the birds were extremely thin and there was a considerable proportion of young birds, though on this occasion the old birds were past the moult and the young ones were now, of course, almost fully grown.

During the terminal stages of the disaster, A. G. Stewart heard that oiled birds were coming ashore in Ayrshire between 26–30 January, and organized an additional beach survey there during the weekend of 2–3 February. By this time oil was already present on the beach at Girvan, Ayr, Prestwick, Troon and Seamill, and more was still coming ashore from Culzean to north of Dunure. None was seen at sea during an aerial survey of the east side of the Firth of Clyde as far south as Ailsa Craig, so that it seems likely that the slick, which was composed of heavy fuel oil, originated somewhere south of Arran, where oiled birds also came ashore on the south-eastern beaches. The majority of the badly affected ones, mainly Razorbills with many Guillemots

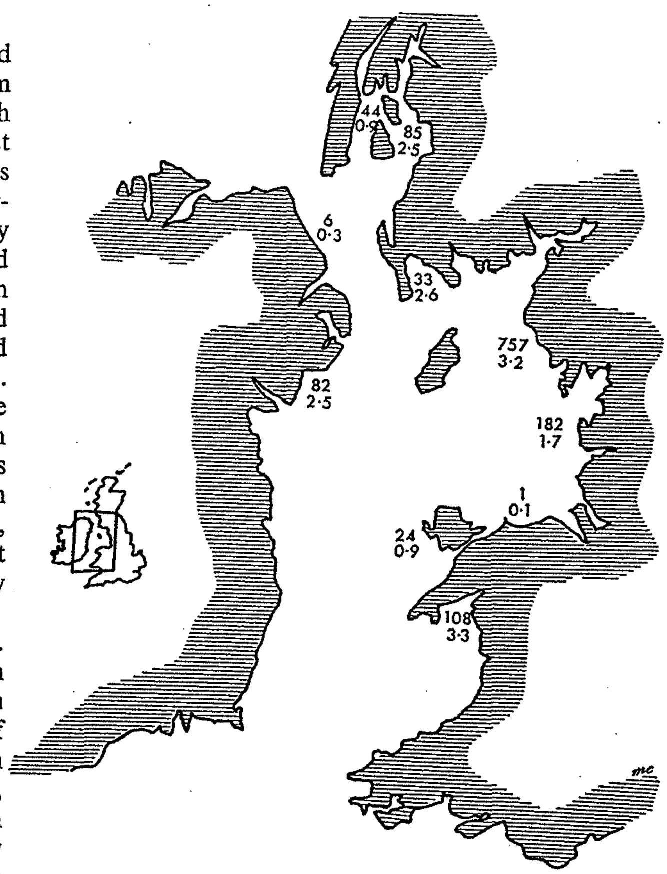

Fig. 1 Distribution of dead birds (total, followed by number per km) found around the Irish Sea and Firth of Clyde during the January, 1974 beached bird survey. The mortality in the Firth of Clyde was subsequently much increased when oil pollution also affected the birds.

TABLE 1

The number and species of dead birds found in the northern Irish Sea and Firth of Clyde during the January 1974 beached bird survey.

	km	Divers	Grebes	Fulmar	Gannet	Cormorant and Shag	Wildfowl	Waders	Gulls and Terns	Auks	Others	Total
Buteshire	52				1	21		1	16	5		44
Ayrshire	34			1		22	8	5	16	33		85
Kirkcudbrightshire	13							1	6			33
Co. Antrim	17					1	1	1	1			6
Co. Down	33					81			·1			82
Cumberland	240	1		3	4	11	38	24	93	582	1	757
Lancashire	108	1	2			9	19	17	54	79	1	182
Cheshire/Flint/Denbigh	15								1			1
Anglesey	27				1	10			8	5		24
Caernarvonshire	33		1			11	8	3	17	67	1	108
Total	572	2	3	4	6	166	74	52	213	799	3	1322

TABLE 2

Comparison of bird mortality and incidence of oil pollution in the north Irish Sea and the east coast of Scotland in 1973 and 1974.

Species	East Scotland				North Irish Sea			
	1973		1974		1973		1974	
	Birds/km	Oiled	Birds/km	Oiled	Birds/km	Oiled	Birds/km	Oiled
Auks	0·06	40%	0·13	39%	0·16	81%	1·38	11%
Phalacrocoracidae	0·02	29%	0·04	0%	0·04	9%	0·29	12%
All species	0·56	15%	0·56	14%	0·50	34%	2·29	11%

and Eiders (*Somateria mollissima*), came ashore between Girvan and Prestwick, while there were also many oiled gulls and waders on the Culzean–Croy shore with smaller numbers at Ayr, Prestwick, and Troon. Most of the oiled birds came ashore on 28 January, and a few were still present into March, though elsewhere the mortality had returned to normal levels by the time of the next routine beach survey on 23–24 February. The 818 known casualties are listed in Table 3, and it was thought the full total was a little over a thousand.

More ringed auks and especially Phalacrocoracidae were recovered in the area of mortality in January, 1974 than at this time in any of the previous seven years; the number is compared with the average for this period in Table 4 and their distribution has been plotted by Mead (1974a). Most of the recoveries (61 or 91%) were made between 9 January and 20 February. Many of the birds had been ringed on the Great Saltee or Lambay in the south-west Irish Sea, and 88% were under 4 years old. A similar northward displacement of debilitated birds or bodies was recorded in the autumn of 1969 (Mead, 1974b). While the auks at least may disperse north regularly at this season (Bourne, 1971), it seems doubtful whether this movement normally occurs on such a large scale or lasts until January, unless the birds are short of food or weakened and unable to make headway against the prevailing south-west winds and northward drift of surface water.

An experiment to investigate the fate of marked bird bodies by the RSPB Research Department in the same area as the wreck chanced to coincide with the closing stages. A total of 300 dead Herring Gulls (*Larus argentatus*) and 19 dead auks were thrown overboard at intervals from the ferry between Liverpool and Douglas on the Isle of Man on 29 January. Only 24 (7·5%) of the bodies were subsequently reported compared with 58% for a similar experiment the previous year (Bibby & Bourne, 1974). The extremely unsettled weather with strong but variable winds which may have taken a long time to drift the bodies far and then landed them on unfrequented shores may help explain the poor recovery rate. Weakened birds are likely to swim or drift close to the shore before they die, so their recovery rate may be higher, but even so this observation suggests that the 1,600 bodies reported (compared with 12,000 in 1969) represent only a fraction of the mortality.

TABLE 3

Oiled birds recorded in Ayrshire in January–February, 1974.

Species	Alive	Dead	Total
Razorbill *Alca torda*	98	170	268
Guillemot *Uria aalge*	43	58	101
auk sp.	–	2	2
Herring Gull *Larus argentatus*	103+	3	106+
Eider *Somateria mollissima*	52	31	83
Black-headed Gull *Larus ridibundus*	70+	–	70+
Oystercatcher *Haematopus ostralegus*	36+	–	36+
Kittiwake *Rissa tridactyla*	32	1	33
Common Gull *Larus canus*	18+	1	19+
Cormorant *Phalacrocorax carbo*	12	5	17
Redshank *Tringa totanus*	14+	–	14+
Red-breasted Merganser *Mergus serrator*	6	6	12
Mute Swan *Cygnus olor*	7	4	11
Others	25	21	46
Total	516	302	818

The numbers followed by + are minimum estimates of birds seen together at one time. The other species included nine Shags *Phalacrocorax aristotelis*, eight Curlew *Numenius arquata*, five Black Guillemots *Cepphus carbo*, four Shelduck *Tadorna tadorna*, Gannets *Sula bassana*, and Great Northern Divers *Gavia immer*, three Great Black-backed Gulls *Larus marinus*, two Black- and Red-throated Divers *Gavia arctica* and *G. stellata* and Goldeneye *Bucephala clangula*, and one Mallard *Anas platyrhynchos*, Glaucous Gull *Larus hyperboreus* and Little Auk *Alle alle*.

TABLE 4

Number of ringing recoveries from the Irish Sea area in 1974 compared with the previous seven years.

Species	Average: 1967–73 January	Average: 1967–73 February	1974 January	1974 February
Cormorant	2·6	2·4	6	4
Shag	4·0	6·0	43	24
Razorbill	0·1	0·1	1	4
Guillemot	0·6	0·4	2	3

Post-mortem Examinations

Two Guillemots, two Razorbills and a Red-throated Diver (*Gavia stellata*) were investigated by D. Taylor and E. Wheeldon at the University of Glasgow Veterinary School, and a Guillemot and two Shags with the help of Mrs H. M. Hanson at Monks Wood Experimental Station. Some details of these and other specimens examined are also recorded in Table 5. In general, the birds were 20–40% underweight compared with breeding adults, with loss of most fat deposits, though the pectoral muscles were not always as wasted as in 1969; they also had fluid or frothing in the lungs. The Diver and Razorbills were oiled, which explains their death. Guillemot M4417 had blood on the bill and trachea and water in the lungs, and may have drowned after a blow on the neck. (It was the heaviest bird received at Monks Wood, five others ranging between 470–610 g (average 553 g). Guillemot B289, found dead on the beach at Kilcreggan, was only a little lighter, and the only significant finding was fluid in the lungs. Guillemot B283, found beached beside the River Nith at Glencaple, was much lighter (about 40% underweight) with a congested carcass and patchy discoloration of the kidney; a gram-negative coccobacillus pathogenic to mice was isolated from the liver. The two Shags M4118/9 were also about 30% underweight compared with breeding females in summer; their intestines were congested with haermorrhage and the kidneys full of urates and apparently malfunctioning, while in one the heart was congested. Together with the Razorbills they had nematodes in the gizzard, but this is not unusual.

Toxic Chemical Analyses

Details of 22 specimens which were analysed for organochlorine insecticide and PCB residues are given in Table 5. In half of them estimates are available for muscle as well as liver. In general, the Guillemots showed lower liver values and perhaps slightly higher muscle ones (at least compared to whole body values:

TABLE 5

Toxic chemical residues in ppm. wet weight in seabirds collected January–February, 1974.

No.	Species	Age/Sex	Origin	Weight	Oil	Tissue	PCBs	DDE	Dieldrin
B287	Red-throated Diver	ad.m.	Dumbarton	1248g	+	liver	123	19·1	5·0
						muscle	41	17·1	1·6
C1	Cormorant	f.	Ayrshire	–	0	liver	23	0·4	1·9
						muscle	5	0·2	1·6
B276	Shag	imm.f.	Ayrshire	1270g	+	liver	10	2·5	0·9
M4118		imm.	Bute	1105g	0	liver	7	1·2	1·1
M4119		imm.	Bute	1160g	0	liver	8	1·4	1·6
B273	Eider	ad.m.	Ayrshire	2470g	+	liver	4	0·6	1·0
B274		ad.f.	Ayrshire	1420g	+	liver	16	4·1	1·6
C2		ad.m.	Ayrshire	–	0	liver	18	1·3	0·8
						muscle	7	1·2	0·8
C3		ad.f.	Ayrshire	–	0	liver	35	5·4	2·8
						muscle	3	0·2	0·4
C4	Guillemot		Ayrshire	–	0	liver	16	0·5	0·1
						muscle	3	0·2	0·02
C5			Ayrshire	–	0	liver	143	22·3	1·0
						muscle	23	0·4	0·6
M4117		imm.	Bute	730g	0	liver	13	3·1	0·6
B279		imm.	Ayrshire	630g	+	liver	98	7·1	–
B290		imm.	Arran	538g	+	liver	126	13·9	1·3
B289		ad.f.	Dumbarton	634g	++	liver	41	6·6	1·2
B284		ad.f.	Dumbarton	660g	0	liver	33	8·6	0·5
						muscle	6	1·7	0·1
B283		ad.m	Solway	576g	0	liver	18	6·3	0·07
						muscle	3	1·1	0·02
B291		imm.	Solway	575g	0	liver	6	1·2	0·1
						muscle	1	0·2	0·02
B292		imm.	Solway	561g	0	liver	40	3·2	0·5
						muscle	8	1·3	0·2
B277	Razorbill	ad.	Ayrshire	445g	+	liver	63	4·1	1·6
B285		ad.f.	Dumbarton	415g	+	liver	98	11·8	0·8
						muscle	16	1·8	0·2
B288		imm.f.	Dumbarton	443g	+	liver	20	3·0	1·3

B, analysed by Dr J. A. Bogan, Glasgow University.
C, analysed by Dr G. Best, Clyde River Purification Board.
M, analysed at Monks Wood Experimental Station.
ad., adult; imm., immature (normally first year).
Ayrshire birds normally found near Troon, Buteshire birds from Isle of Cumbrae, Dumbartonshire birds from Rhu, Helensburgh or Kilcreggan.

Holdgate, 1971; Parslow & Jefferies, 1973) than in 1969, which may indicate that the 1974 birds died sooner, before so much organochlorine material, liberated from lipids, had accumulated in the liver. Among the other species examined, the Eiders, Cormorants and Shags had fairly low muscle organochlorine levels, but two to twelve times these amounts in the liver. The Razorbill whose muscle was examined had a rather high PCB level, and the Red-throated Diver rather high levels of all three organochlorine materials in both liver and muscle, for a bird which was still alive and had only begun to show a limited amount of concentration in the liver. It is notable that the species feeding inshore in the Firth of Clyde (the Eiders, Phalacrocoracidae and the Diver) show comparatively high dieldrin levels compared to most of the auks, which normally feed further out to sea. Some auks from the Firth of Clyde also had levels of dieldrin several times higher than any reported during the 1969 bird-kill, however, when unfortunately none of the birds from that area was investigated for dieldrin.

The livers of two Shags and a Guillemot (M4117–9) were also tested for certain heavy metals at Monks Wood, where all analyses were carried out by M. C. French, Miss C. Brown and L. Sheppard. They were found to contain 4·1–5·1 ppm mercury, 10–23 ppm copper, 0·11–0·31 ppm cadmium, 30–79 ppm zinc and under 0·2 ppm lead, wet weight.

Discussion

The initially cold and continuously stormy winter of 1973/74 may provide an explanation for this seabird mortality. The distribution of the bodies was very similar to that found in 1969, though there were only about a tenth as many, and other species were represented as well as the auks on this occasion, especially the Phalacrocoracidae, which are also already known to be prone to sudden high mortality at intervals (Potts, 1969). It now seems increasingly clear that the locations in which bodies wash up must be due more to the pattern of atmospheric and oceanic circulation up the west coast of Britain than to any particular features of the places concerned, except where oil pollution intervened during the terminal stages of both the 1969 and 1974 wrecks in the Firth of Clyde. It seems as difficult to assess the potential role of toxic chemical pollution in increasing the vulnerability of the birds now as it was in 1969. The post-mortem results remain inconclusive; the birds appear to have died of a variety of causes, and the only frequent findings are wasting and perhaps fluid in the lungs, which could well be due to a terminal heart or renal failure, or to a fall in plasma proteins. As in 1969, relatively high levels of PCB were present in the birds, and in addition it is notable that elevated levels of dieldrin were found in the birds from the Clyde. Whatever the effect of these man-made compounds may be, their presence is surely undesirable.

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Reduction of Field Populations of Fiddler Crabs by Uptake of Chlorinated Hydrocarbons

Fiddler crabs are particularly sensitive to chlorinated hydrocarbons. Crabs that have been feeding on contaminated material show an impairment of their escape reaction. High concentrations of Aldrin and Dieldrin in plots of marsh experimentally treated with contaminated sewage sludge indicate that these insecticides are responsible for a drastic reduction in fiddler crab populations.

The contamination of coastal waters by effluents from sea outfalls and ocean-dumping of sewage sludge and industrial wastes containing chlorinated hydrocarbons is commonplace (Pearce, 1969; Oden, *et al.*, 1970; Holden, 1970; Schmidt, *et al.*, 1971; Greve, 1971; Burnett, 1971). We have demonstrated the presence of high concentrations of persistent chlorinated hydrocarbon insecticides in a commercial sewage sludge fertilizer and the uptake of these insecticides under field conditions by the estuarine detritivore, *Uca pugnax*. The resulting disruption of the fiddler crab populations has been demonstrated and will be more extensively documented elsewhere (Krebs, *et al.*, in preparation).

Fiddler crabs (*Uca pugnax*) are particularly sensitive to chlorinated hydrocarbon contamination of sediments (Odum, *et al.*, 1969; Nimmo, *et al.*, 1971). Elimination of fiddler crabs has been reported with the experimental application of Dieldrin, Strobane, DDT, and BHC to salt marshes (Croker & Wilson, 1965; Harrington & Bidlingmayer, 1958; George, *et al.*, 1957). DDT residues in the Carmans River marsh sediments (Long Island, New York) have been implicated in the disappearance of fiddler crabs (Odum, *et al.*, 1969). Crabs show selective feeding behaviour in which mud and detritus are sorted and only the smallest particle size ingested (Miller, 1961; Ono, 1965). Although rich in calories (Odum & de la Cruz, 1967), these fine particle sizes also contain the highest concentrations of chlorinated hydrocarbon insecticides in natural marsh sediments (Odum, *et al.*, 1969).

Effects of Sludge Fertilizer on Crabs

A commercial fertilizer manufactured from sewage sludge was added to plots (20 m diameter) in Great Sippewissett Marsh, West Falmouth, Mass., to test the effects of contamination on salt marsh ecosystems. Weekly doses of 25·2 g/m² (HF) and 8·4 g/m² (LF) of the sludge fertilizer were added at low tide to each of two replicate plots from May to November, 1970. Two untreated plots served as controls. Details of the treatments are given elsewhere (Valiela, *et al.*, 1973).

Fiddler crabs begin hibernation in underground burrows during the fall, as the first frosts arrive. Censuses of 1 m² areas taken during early November showed lower densities of crabs beginning to over winter in the plots at the higher dose of sewage-contamination (Table 1). In addition, both dosages increased the number of crabs found dead or inactive on the marsh surface. Live crabs collected from the surface of the treated plots were unable to move and were therefore in danger of freezing. The locomotor impairment was recreated in normal crabs by 10 days of laboratory feeding on sediments from the treated plots. The usually rapid escape response (Verwey, 1930; Clark, 1935; Kunze, 1963) was very slow or absent (Table 2). This effect was assayed using a mechanical device which moved a black square (5×5 cm) across the visual field of a crab twice each second, and measuring the escape response as the time it took for the crab to move out of a 20 cm diameter circle.